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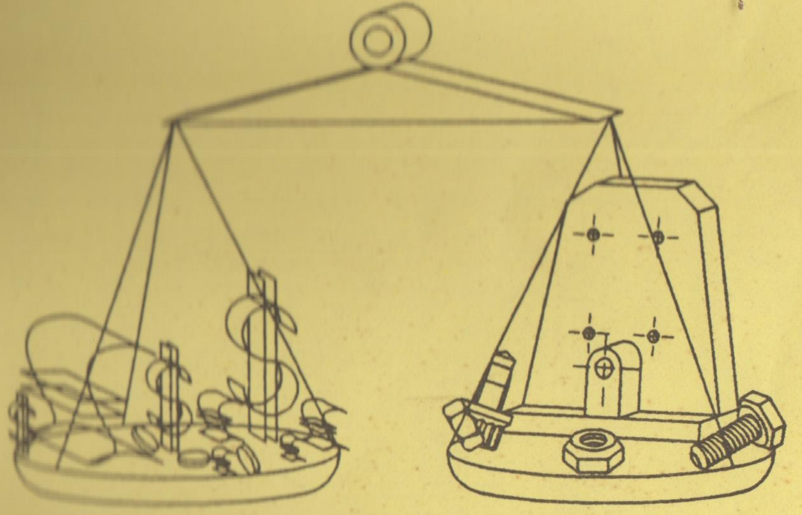
BRITISH AEROSPACE
DYNAMICS
HATFIELD/LOSTOCK DIVISION
HATFIELD HERTFORDSHIRE

COST GUIDE FOR ENGINEERS



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1. INTRODUCTION

There is a self-evident need for Design Engineers to be closely involved with the achievements of Cost Targets. A detailed drawing is not just a method of conveying information but it is a financial commitment relating to material, manufacturing methods and tolerances which demand capital expenditure, and will eventually determine the total cost of the finished article. Engineers are continuously being urged to design for economical manufacture and low cost. However, without any data on which to base their efforts, success is not surprisingly, limited.

It is important to establish in terms of cost, which design aspects conflict or augment one another. These can be divided into two groups:

Product Characteristics	Manufacturing Characteristics
operational requirements	purchasing)
design requirements	manufacturing) = cost
	stock items)

Product characteristics of design must be met by the designer, but cost applies right across the manufacturing category. Cost is as much an attribute of design as is performance, strength, weight, reliability, etc. With manufacturing production costs approaching 50p/minute the scope for saving on cost is clearly immense.

The accuracy demanded in a particular part has a large bearing on the economics of that item. The largest section in this Cost Guide concentrates on the effects of tolerances on cost.

2. TOLERANCES

The accuracy demanded in a particular part is the major portion of the total cost of manufacture. Figure 1 shows the relative cost of various machine and hand processes for achieving set tolerances. Figure 2 shows that an easy location fit can be double the cost of an easy running fit. It is essential that designers appreciate the high cost of applying limits as it is often seen in practice that, they opt to 'play safe' specifiying unnecessarily narrow tolerances. "Hang a £ sign on every tolerance" and ask the questions:

(a) What is the tolerance for?

(b) What can be done to widen it?

(c) Can the tolerance be removed?

For the operator on the machine, a tolerance is a force to reckoned with. Using a compensating element allows tolerances to be wide, the required fit being obtained by introducing an adjustable component element into the tolerance chain. This gives advantages of:

(a) Simplicity of assembly along with high accuracy.

(b) Possibility of making adjustments on assembly.

A suitable tolerance is one where most out of tolerance components raised on reject notes have to be rejected, since continued acceptance of such parts shows that the original tolerance should have been eased.

Tolerances on internal diameters cost approximately twice that of external diameters. The relative costs of the 4 basic shaft fits from ST269 are shown in Figure 2. Tolerances commensurate with ST269 should be observed wherever possible. Deviations from H8 to H7 hole tolerances are not only costly due to non-availability of standard tooling, but, as is shown in Figure 3, are more costly to produce.

Figure 4 shows the cost of accuracy with order of complexity of processing elments.

Figure 5 to 11 give a quick appreciation of the consequences of changing the tolerance on a component.

The seven charts are:

Fig. 5	External Diameter	)
Fig. 6	Internal Diameter	) on a part that
Fig. 7	Face of an Internal Diameter	) can be revolved
Fig. 8	Internal Diameter	)
Fig. 9	Face of an internal diameter to a datum	) on a part that) cannot be revolved
Fig. 10	Gear centres or Internal Diameter to a datum	)
Fig. 11	Plain face to a datum	- on a frame or baseplate

The following procedure describes the use of the charts:

1. Select tolerance from STP269 "Preferred Range of Dimensional Limits and Fits for Holes and Shafts".

2. Identify appropriate chart.

3. Consider whether the tolerance can be reduced or if an alternative preferred tolerance would meet functional requirements.

4. Use the chart to find the relative cost difference and select the lowest cost possible.

5. Consider the percentage scrap anticipated.

Example

The diameter of a shaft requires a tolerance. The designer feels that 0.075 mm would suffice, however, 0.04 mm is also being considered. Reference to Fig. 5 shows that the relative cost will be 2.75 times to produce the smaller tolerance with an expected scrap rate of 1%.

3. STANDARDIZATION

One of the most effective methods of cost reduction is achieved by reducing the number of different component types used throughout the assembly. This is of particular significance when considering fasteners. In production, any aid towards commonality will cut the assembly manufacturing costs and the tool manufacturing costs dramatically.

In general, the least number of parts equals the least cost because expensive interfaces are removed.

Work to preferred lists of fasteners (screws, nuts, bolts, etc.). Keep the number of different size threads, used on components and assemblies to a minimum. This saves the cost of tool changes and reduces the chance of mistakes.

Aerospace standard materials in channel, hex., tee and angle sections are worth consideration for medium or high production items. The high cost of machining from solid is saved.

Where the design requirements of AvP24, 32 and 970 (Def Stan 00-970) are not specifically called for, ie. ground equipment, test rig, etc., commercial materials should be used as they are less expensive and more easily obtained.

4. DIMENSIONING

A common fault among detail designers is that of specifying tolerances from an unsuitable manufacturing datum. This can often result in increased manufacturing costs and assembly difficulties. When considering the dimensions of a component, the important functional features should be determined first. This should be followed by the consideration of production methods in order to establish the manufacturing datums. It is quite common for the manufacturing and functional datums to be at different locations, in which case the manufacturing drawing should use the manufacturing datum, whilst ensuring that the functional aspects are maintained.

Figures 13 and 14 show a typical example of dimensioning to meet functional and manufacturing requirements.

Figure 15 shows the cost of positioning bores in relation to a datum face.

5. SURFACE FINISH

The relative costs of producing specific surface textures are shown in Fig. 16. The definition of surface texture and tolerance are obviously very closely related. Fig. 17 shows the accuracy that can be expected from operators using lathes, boring, grinding and honing machines.

When machining components, the ability to hold the part has an important bearing on the level of finish likely to be achieved, and also the likelihood of scrapping the part. Design of a particular holding fixture is not the design engineer's responsibility, but designers can influence the holding characteristics during machining by considering these aspects during the initial design stages.

STP212, Surface Testure Design Requirements gives achieveable surface finishes for particular machines and should be consulted.

Designers should show the areas where a good surface finish is required rather than indicating an all over surface finish.

6. MACHINING

Typical machining times for various materials are shown in Fig. 18. Once the designer has decided on the most economical material and production process, he or she needs to be aware of the best way to design the component, for lowest cost using the selected method of manufacture. Close liaison is essential between the designer and the resident production engineer. The following general information is included as a guide to help reduce manufacturing costs.

Drilling

Fig. 19 shows drilling costs for various depths of holes.

Add 10% for material $\geq$ 675 MN/m^2

Add 20% for handling large or awkward components

time to countersink hole - basic cost

time to counterbore hole - add 200% to basic cost

time to spotface hole - add 200% to basic cost

time to back s'face - add 500% to basic cost

Grinding (with 0.25 mm to 0.375 mm grinding allowance)

(i) Cylindrical

Ball race diameters - add 25% to basic cost
Micro-finish - add 50% to basic cost
Tungsten-carbide - add 100% to basic cost

(ii) Internal

Micro-finish - add 50% to basic cost
Blind hole - add 25% to basic cost
Thin walled jobs - add 25% to basic cost

Note: thin wall thickness is 2 mm minimum, 6 mm maximum

(iii) Surface (18" and 60" machines)

Bottom faces of slots - add 50% to basic cost
Side faces of slots - add 100% to basic cost
Forming radii - add 100% to basic cost
Machining to 0.2 m CLA - add 50% to basic cost
Locating from bore (no fixture) - add 200% to basic cost
Weight 3kg - add 20% to basic cost
For every kg over 3kg - add 10% to basic cost
Grinding brass - add 75% to basic cost
Clean up or to limits - clean up - add 10% to basic cost
Limiting widths - add 25% to basic cost
Limited slots - add 50% to basic cost

Jig Boring and Jig Milling

Aluminium and brass - minus 10% from basic cost
Bores in line - add 10% to basic cost
SG iron - add 15% to basic cost
Limited counterbores - add 20% to basic cost
Bronze and steel - add 25% to basic cost

Turning

Basic cost for steel $\leq$ 675 MN/m^2
For limited diameters, screwing and tapping - double basic cost.

675-750 MN/m^2 steel - add 15% to basic cost
825 MN/m^2 steel - add 25% to basic cost

Milling (horizontal and vertical)

The guide lines given in STP242 covering milling and spotface cutters have important cost implications when determining corner radii, sweep clearance, close toleranced slots and cutter sizes.

Chart times are for steel $\leq$ 425 MN/m^2 (jobs held securely)

Brass and aluminium alloy - minus 50% from basic cost

CI and gun metal - minus 15% from basic cost

Bronze, St. St., Steel $>$ 425 MN/m^2 - add 40% to basic cost

Tool steel, etc. - add 60% to basic cost

7. DETAIL DESIGN

Because designers work to very tight time schedules they often adopt a "belt and braces" approach which can lead to unnecessarily complex and expensive designs. More money spent in design can reap large savings in production.

The following cost guide shows the aspects of detail design which will produce significant cost savings.

Section 3.21 of STH50, Design for Production, should be consulted for additional details covering machining, sheet metal and castings.

8. RAW MATERIAL COSTS

Raw material relative costs are shown on the following charts (Figs. 20 to 22) for:

(i) Ferrous and non-ferrous bar
(ii) Ferrous and non-ferrous sheet
(iii) Ferrous and non-ferrous castings

The charts show comparison by volume so that a direct cost comparison for an alternative material is shown.

Figs. 23 and 24 show the cost comparison of various plating processes and alternative finishes.

9. DO'S AND DONT'S

DON'T forget $\overset{1.6}{\checkmark}$ indicates a surface finish requirement of 1.6 µm cla and is not an instruction to machine, eg. milling, turning, etc.

DON'T use superior finish unless essential.

DON'T use handfinishing if machine finishing is sufficient.

DON'T leave dimensions open if they can be made larger than shown in SD14675.

DON'T use closer tolerances than necessary.

DON'T alter standard hole tolerances for an alternative fit - but if necessary alter male dimensions.

DON'T miss checking the availability of suitable stock proprietary items and thus economise on our own manufacture.

DON'T miss checking with data book and Standards Department for parts already existing with emphasis on preferred items.

DON'T use sizes of material not shown in the Company's stock list.

DON'T machine stock material unless superior finish is essential.

DON'T use a higher grade material than is necessary (for reason of machineability and prime cost).

DON'T machine from solid if quantities would justify casting, moulding, etc.

DON'T forget that special tools are very costly, check in Standards Publication and Planning Department for existing sizes available; eg. broaches, punches, counterbores, wiederman, etc.

DON'T machine apertures, gaps, etc. in castings if these could be cored.

DON'T forget that small tapped holes are a potential trouble source.

DON'T forget note on keyway alignment, eg. 'Alignment of keyways not important'.

DON'T use more fixing holes and screws than necessary.

DON'T leave operators to calculate dimensions, angles, etc.

DON'T use a higher class gear than is needed.

DON'T use more than one place of decimals for sheet metal dimensions.

DON'T issue unchecked drawings: Modifications later are very costly.

DON'T give other Departments the need to query any part of your drawing.

DON'T use complicated sheet metal shapes. Special tools may be required for double curvature parts.

DON'T call for mechanical engraving if photo-anodising is possible.

DON'T harden complete on large or slender sections if a hard (spray) face or hard insert will do.

DON'T use welding; this process has distortion problems, jigs will be required to control. If welding unavoidable, try to design self locating joints, keep number of joints to minimum.

DON'T use small diameter deep holes.

DON'T use different size corner rads. saves changing milling cutters.

DO YOU KNOW THAT EVERY ALLOWED MINUTE PAID FOR PRODUCTION TIME, COSTS ABOUT 50 PENCE

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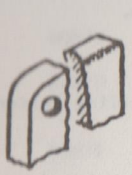
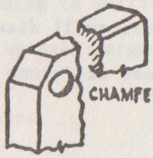
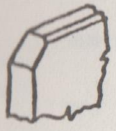
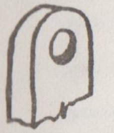
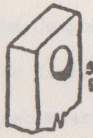
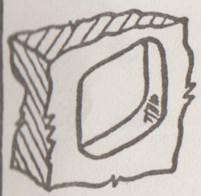
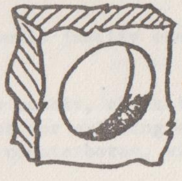
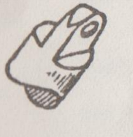
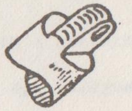
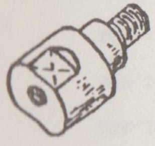
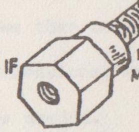
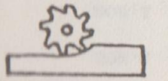
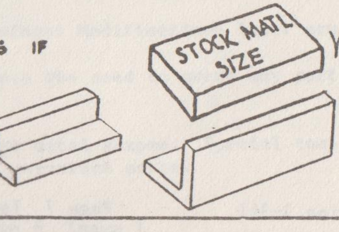
 DON'T RADIUS CORNERS & EDGES IF  CHAMFERS WILL DO	1½:1 IF RADIAL FROM A HOLE 4:1
 DON'T CHAMFER CORNERS & EDGES IF BROKEN EDGES WILL DO	5:1
 DON'T RADIUS ENDS OF LINKS ETC. IF  SQUARE ENDS WILL DO	5:1
 DON'T MAKE SHAPED MACHINED APERTURES IF ROUND  WILL DO	4:1
 DON'T USE MILLED RADII ON ENDS IF  WILL DO	2:1
 DON'T MILL SPANNER FLATS ON ROUNDS IF  HEXAGON MATERIAL WILL DO	3:1
 DON'T MACHINE FACES IF  WILL DO	

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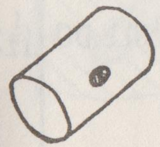
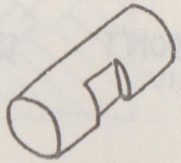
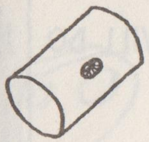
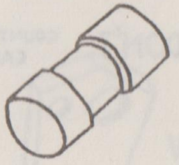
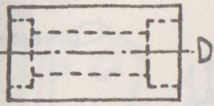
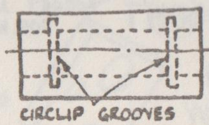
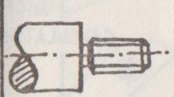
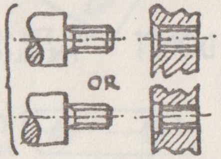
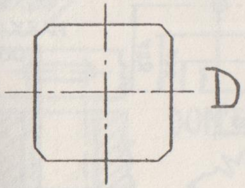
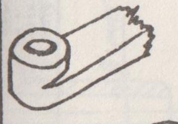
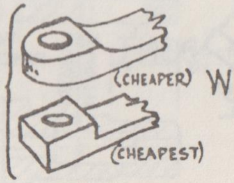
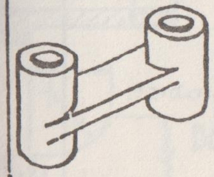
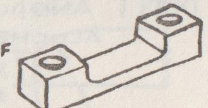
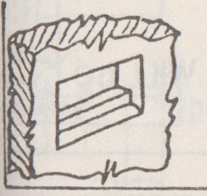
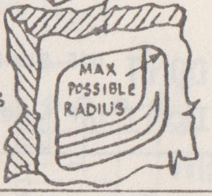
 DON'T USE DIMPLES FOR TRANSMISSION COMPONENTS WHEN ADJUSTMENT IS NECESSARY IF  WILL DO	EASE OF ASSEMBLY
 DON'T USE DIMPLES FOR COLLARS IF  WILL DO	SAVES AN OPERATION
 DON'T C/BORE FOR BEARINGS ETC IF  CIRCLIP GROOVES WILL DO	2:1
 DON'T UNDERCUT THREADS IF (SEE STP262)  WILL DO	4:1
 DO GIVE ALTERNATIVE CHAM OR RADII	SAVES SETTING UP TIME
 DON'T MACHINE ROUND BOSSES IF  WILL DO	3:1 5:1
 DON'T MACHINE BOSSES BOTH SIDES IF BOSSES ONE SIDE  WILL DO	4:1
 DON'T DEMAND SQUARE CORNERS OR SMALL RADII IN MACHINED APERTURES AND RECESSES IF  WILL DO	3:1 DEPENDS ON SIZE. AVOIDS FITTING OP.

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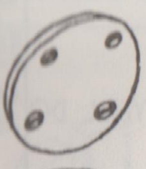
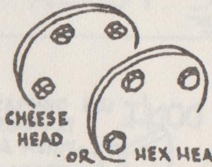
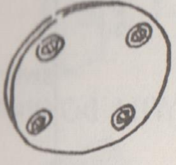
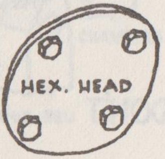
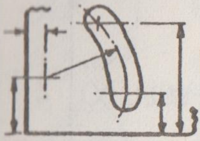
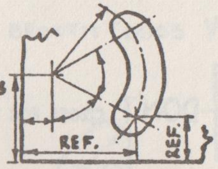
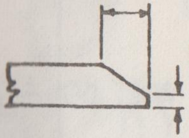
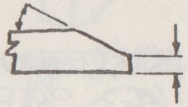
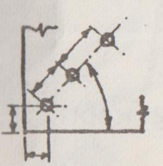
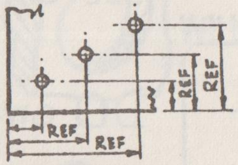
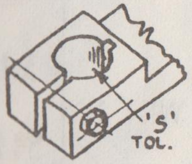
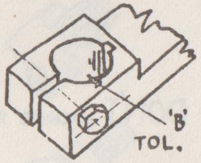
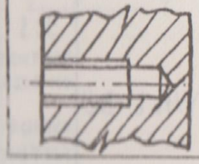
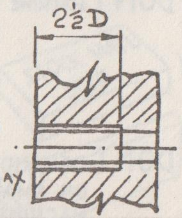
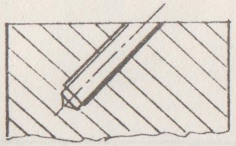
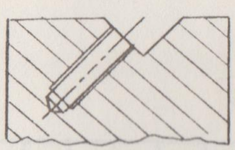
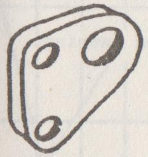
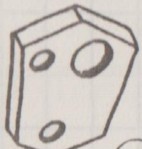
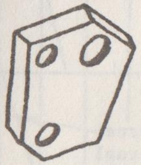
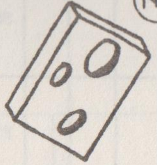
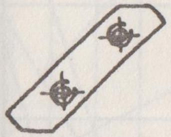
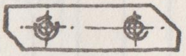
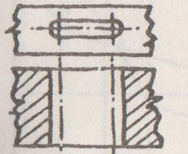
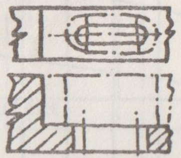
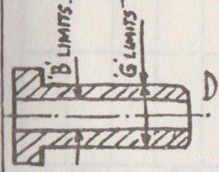
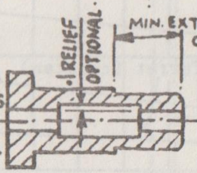
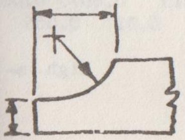
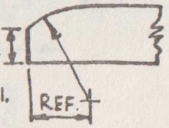
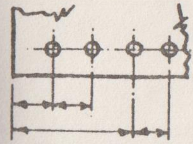
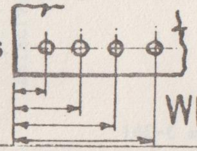
 DON'T COUNTERSINK FOR SCREWS IF CHEESE HEAD OR HEX HEAD  WILL DO	1½:1
 DON'T COUNTERBORE FOR SOCKET CAP SCREWS IF HEX. HEAD  WILL DO	1½:1
 DON'T FORGET ANGULAR DIMNS FOR MILLED RADIAL SLOTS 	NEEDED BY OPERATOR
 DON'T OMIT THE ANGULAR DIMNS FOR MILLED SLOPING FACES 	SAVES SHOP CALCULATIONS
 DON'T USE ONLY ANGULAR DIMENSIONS FOR HOLES BUT ADD THE CO-ORDINATES AS REF DIMENSIONS. (MARK AS 'REF') 	EASIER MARKING OUT
 DON'T USE 'S' TOL. TOLERANCE FOR PINCH FITS USE 'B' TOL. 	1½:1
PL DON'T ANODISE IF NOT NECESSARY ALOCHROM IS PREFERRED TO ANODISE	
 DON'T USE BLIND TAPPED HOLES  WILL DO DON'T TAP MORE THAN 2½D MAX	1½:1 LESS TAP BREAKAGE

	COST RATIO OR REASON
 DON'T WHEN  WILL DO	REDUCES TAP AND DRILL BREAKAGE
 DON'T DESIGN CURVED SHAPES IF STRAIGHT EDGES  WILL DO EXCEPT (NC) DRGS.	2:1 SIMPLER MACHINING
 DON'T MACHINE AT OTHER ANGLES IF RIGHT ANGLES  WILL DO	2:1 EVEN SIMPLER MACHINING
 DON'T DRAW AS ASSEMBLED BUT AS OPERATOR WILL HANDLE 	DRG. EASIER TO READ
 DON'T SLOT DRILL THRO' THICK SECTIONS-MAX 2×DIA ≤ 5/16" DIA (REDUCE THICKNESS BY M/CING OR C/BORING IF NECESSARY) 	2:1 TOOLS NOT READILY AVAILABLE SAVES CUTTER BREAKAGE.
 DON'T MAKE CLOSE-LIMITED FEATURES OVER-LONG, MAKE ALLOWANCES AS EXAMPLES. SIMILAR FOR MILLED PARTS. 	REDUCES SCRAP RISK
 DON'T GIVE CENTRE DIMENSIONS FOR CONCAVE RADII. BUT DO GIVE REF. CENTRE FOR CONVEX RADII. 	DIMENSIONS NEEDED BY OPERATOR
 DON'T QUOTE STEPPED DIMENSIONS IF DIMENSIONING FROM DATUM FACE  WILL DO	EASE OF MARKING-OUT

COST OF VARIOUS MACHINE AND HAND PROCESSES FOR ACHIEVING SET TOLERANCES

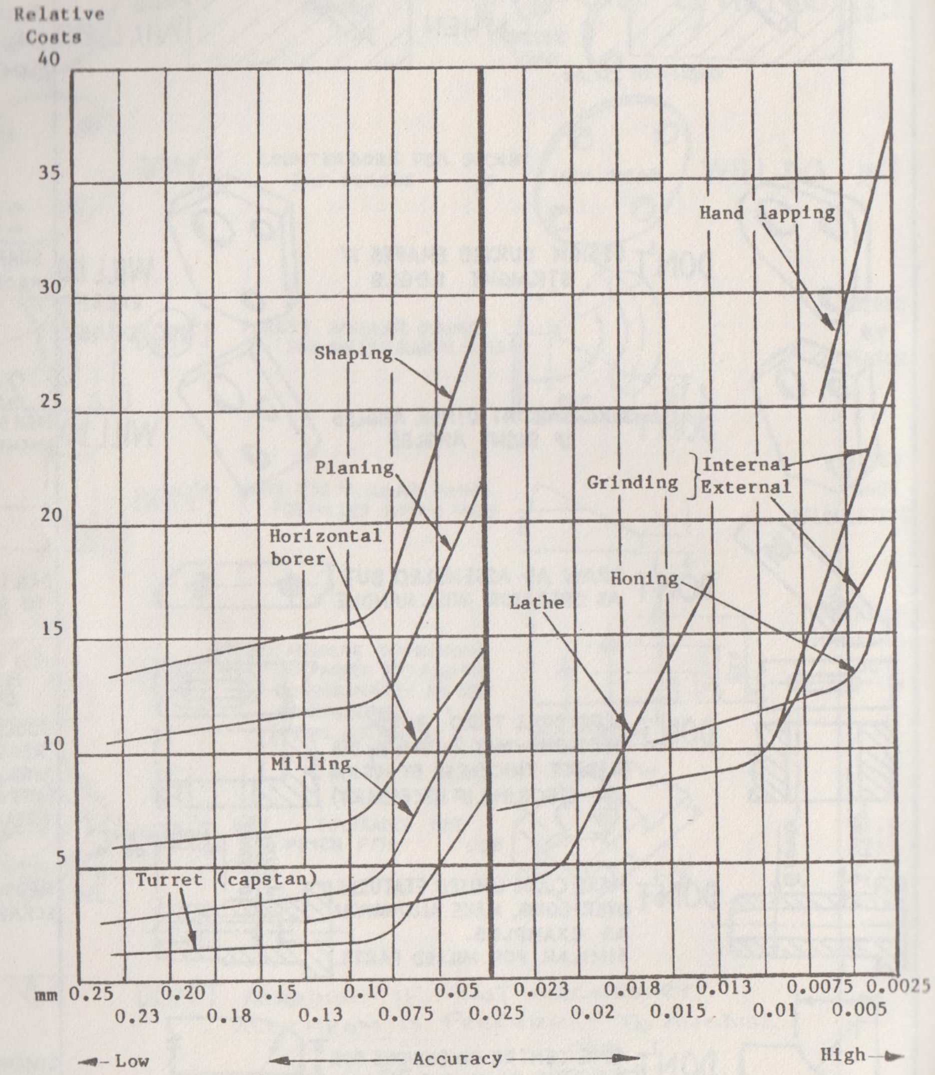


Fig. 1

RELATIVE COSTS OF SHAFT TOLERANCES TO STP269

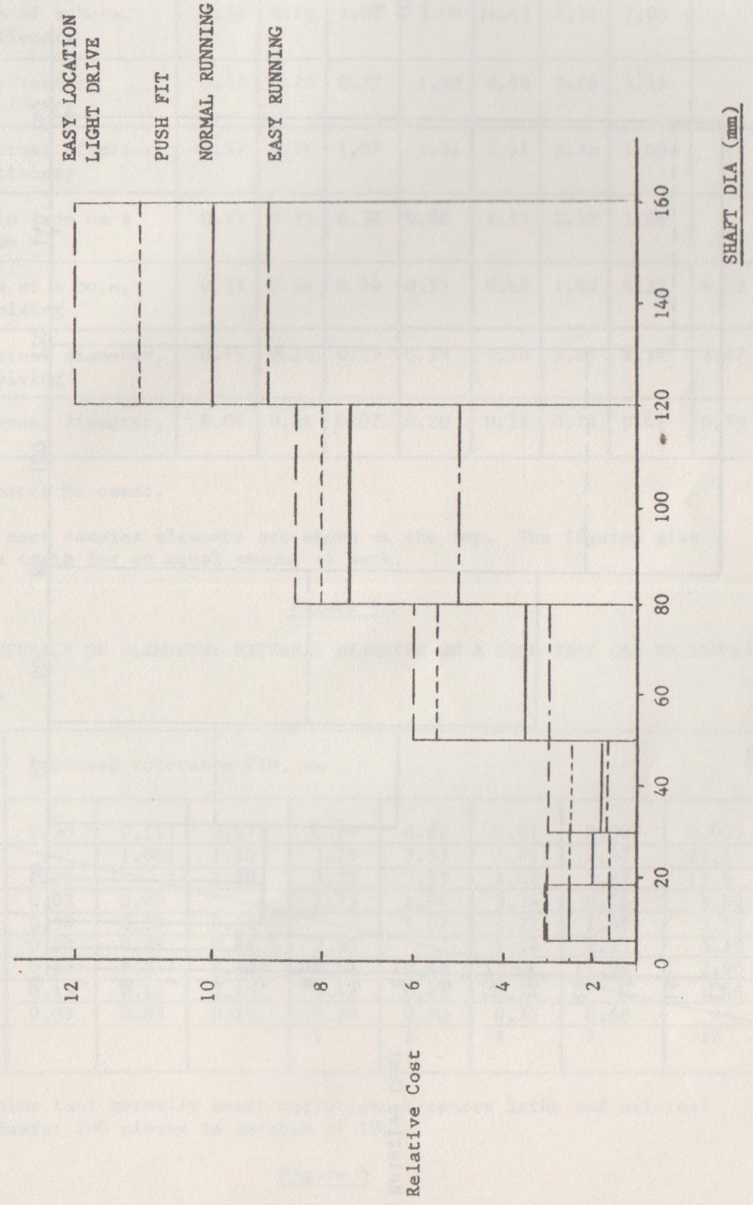


Figure 2

RELATIVE COST OF PRODUCING H7 & H8 TOLERANCED HOLES

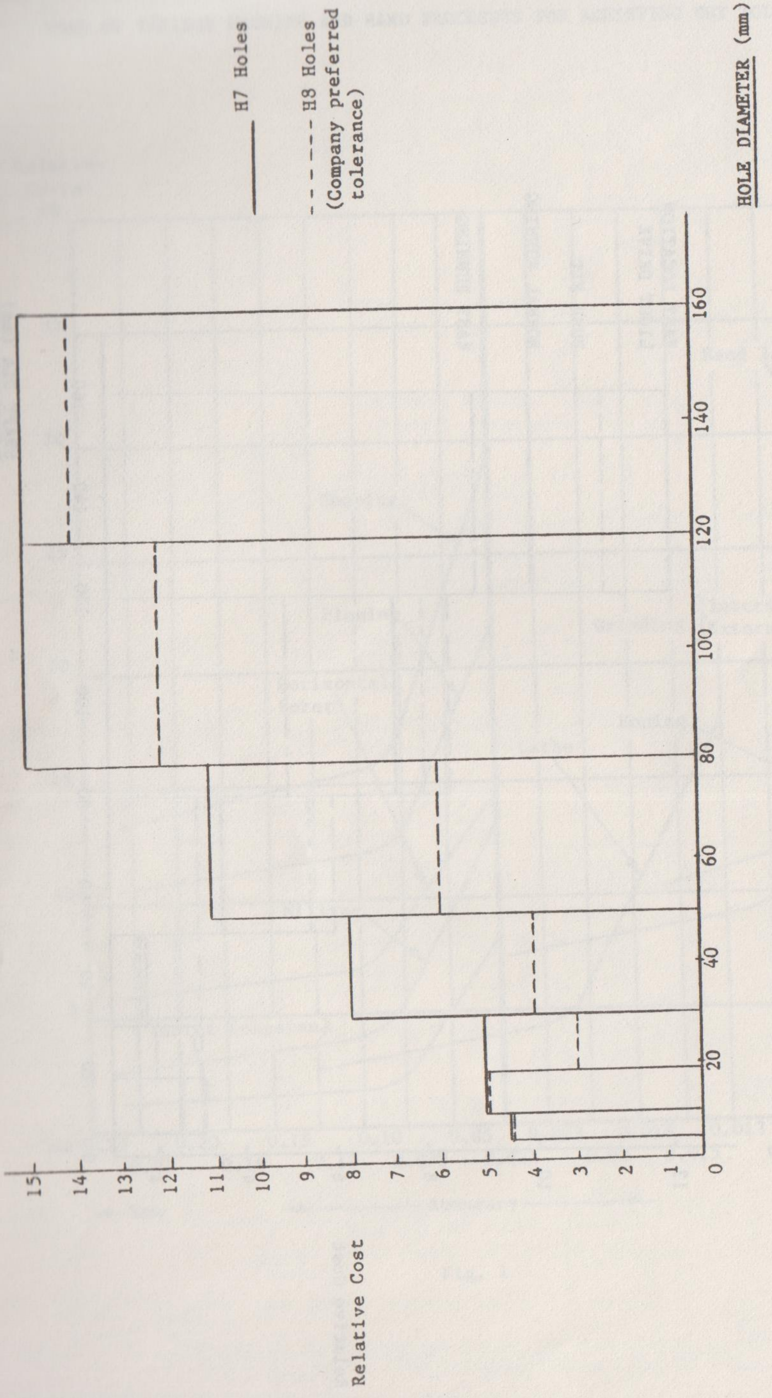


Figure 3

COST OF ACCURACY: ORDER OF COMPLEXITY OF PROCESSING ELEMENTS

No.	Element	Tolerances on element FIM*, mm							
		0.20	0.15	0.075	0.04	0.02	0.01	0.005	0.003
Fig.									
11	Face of a bore, stationary	0.56	0.70	1.02	2.00	4.43	5.55	7.06	
10	Gear centre, stationary	0.18	0.28	0.37	1.98	2.88	3.46	5.46	
9	Internal diameter, stationary	0.57	0.76	1.07	1.51	2.31	3.32	5.05	
8	Plain face on a frame	0.15	0.31	0.38	0.88	1.16	2.59	3.84	
7	Face of a bore, revolving	0.33	0.38	0.44	0.55	0.68	1.90	4.32	6.52
6	Internal diameter, revolving	0.19	0.24	0.29	0.39	0.50	1.07	2.37	3.67
5	External diameter,	0.06	0.06	0.07	0.20	0.21	0.24	0.47	0.70

*Full Indicator Movement.

NOTE: The most complex elements are shown at the top. The figures give comparative costs for an equal amount of work.

Figure 4

COST OF ACCURACY OF ELEMENTS: EXTERNAL DIAMETER ON A BORE THAT CAN BE REVOLVED

Cost Ratios

Existing tolerance band FIM mm	Proposed tolerance FIM, mm							
	0.30	0.15	0.075	0.04	0.02	0.01	0.005	0.003
0.30		1.00	1.20	3.29	3.53	4.01	7.87	11.6
0.15	1.00		1.20	3.29	3.53	4.01	7.87	11.6
0.075	0.83	0.83		2.75	2.94	3.34	6.56	9.69
0.04	0.30	0.30	0.36		1.07	1.22	2.39	3.53
0.02	0.28	0.28	0.34	0.93		1.14	2.23	3.29
0.01	0.25	0.25	0.30	0.82	0.88		1.98	2.90
0.005	0.13	0.13	0.15	0.42	0.45	0.51		1.48
0.0025	0.09	0.09	0.10	0.28	0.30	0.35	0.68	
% scrap expected				1	2	4	7	12

NOTE: Machine tool normally used: turret/chuck/centre lathe and external grinder. Basis: 200 pieces in batches of 10.

Figure 5

COST OF ACCURACY OF ELEMENTS: EXTERNAL DIAMETER ON A BORE THAT CAN BE REVOLVED

Cost Ratios

Existing tolerance band FIM mm	Proposed tolerance FIM, mm							
	0.30	0.15	0.075	0.04	0.02	0.01	0.005	0.003
0.30		1.25	1.51	2.03	2.59	5.41	12.2	18.9
0.15	0.80		1.21	1.63	2.08	4.33	9.81	15.2
0.075	0.66	0.83		1.34	1.71	3.58	8.10	12.5
0.04	0.49	0.62	0.74		1.28	2.67	6.03	9.33
0.02	0.39	0.48	0.58	0.78		2.09	4.72	7.31
0.01	0.18	0.23	0.28	0.38	0.48		2.26	3.50
0.005	0.082	0.10	0.12	0.17	0.21	0.44		1.55
0.0025	0.053	0.066	0.08	0.11	0.14	0.29	0.65	
% scrap expected			1	2	4	6	9	15

NOTE: Machine tool normally used: turret/chuck/centre lathe and external grinder. Basis: 200 pieces in batches of 10.

Figure 6

COST OF ACCURACY ELEMENTS: FACE OF AN INTERNAL DIAMETER ON A BORE THAT CAN BE REVOLVED

Cost Ratios

Existing tolerance band FIM mm	Proposed tolerance FIM, mm							
	0.30	0.15	0.075	0.04	0.02	0.01	0.005	0.003
0.30		1.17	1.34	1.69	2.07	5.80	13.2	19.9
0.15	0.86		1.15	1.45	1.78	4.97	11.3	17.1
0.075	0.75	0.87		1.26	1.54	4.33	9.83	14.8
0.04	0.59	0.69	0.79		1.22	3.43	7.80	11.8
0.02	0.48	0.56	0.65	0.62		2.80	6.37	9.62
0.01	0.17	0.20	0.23	0.29	0.36		2.27	3.43
0.005	0.076	0.088	0.10	0.13	0.16	0.44		1.51
0.0025	0.060	0.057	0.067	0.085	0.10	0.29	0.66	
% scrap expected			1	2	4	6	9	15

NOTE: Machine tool normally used: turret/chuck/centre lathe and external grinder. Basis: 200 pieces in batches of 10.

Figure 7

COST OF ACCURACY OF ELEMENTS: INTERNAL DIAMETER ON A BORE THAT CANNOT BE REVOLVED

Cost Ratios

Existing tolerance band FIM mm	Proposed tolerance FIM, mm							
	0.30	0.15	0.075	0.04	0.02	0.01	0.005	0.003
0.30		1.34	1.87	2.64	4.05	5.81	8.87	Not normally possible
0.15	0.74		1.39	1.97	3.02	4.33	6.61	
0.075	0.53	0.72		1.41	2.16	3.10	4.74	
0.04	0.38	0.51	0.71		1.53	2.20	3.36	
0.02	0.25	0.33	0.46	0.66		1.43	2.19	
0.01	0.17	0.23	0.32	0.45	0.70		1.53	
0.005	0.11	0.15	0.21	0.30	0.46	0.65		
0.0025	Not normally possible							
% scrap expected			1	2	4	6	9	

NOTE: Machine tool normally used: turret/chuck/centre lathe and external grinder. Basis: 200 pieces in batches of 10.

Figure 8

COST OF ACCURACY ELEMENTS: FACE OF AN INTERNAL DIAMETER RELATED TO A DATUM ON A BORE THAT CANNOT BE REVOLVED

Cost Ratios

Existing tolerance band FIM mm	Proposed tolerance FIM, mm								
	0.30	0.15	0.075	0.04 Jig	0.04 No Jig	0.02	0.01	0.005	0.003
0.30		1.26	1.84	3.60	4.30	7.95	10.0	12.7	Not possible
0.15	0.79		1.46	2.85	3.41	6.31	7.92	10.1	
0.075	0.54	0.69		1.96	2.34	4.33	5.44	6.92	
Jig 0.04	0.23	0.29	0.43		1.19	1.85	2.32	2.96	
No Jig0.04	0.28	0.35	0.51	0.84		2.21	2.80	3.53	
0.02	0.13	0.16	0.23	0.45	0.54		1.26	1.60	
0.01	0.10	0.13	0.18	0.36	0.43	0.80		1.27	
0.005	0.079	0.099	0.14	0.28	0.34	0.63	0.79		
0.0025	Not normally possible								
% scrap expected			1	2	3	4	6	9	

NOTE: Machine tool normally used: turret/chuck/centre lathe and external grinder. Basis: 200 pieces in batches of 10.

Figure 9

COST OF ACCURACY OF ELEMENTS: GEAR CENTRE OR BORE RELATED TO A DATUM ON A BORE THAT CANNOT BE REVOLVED

Cost Ratios

Existing tolerance band FIM mm	Proposed tolerance FIM, mm								
	0.30	0.15	0.075	0.04 Jig	0.04 No Jig	0.02	0.01	0.005	0.003
0.30		1.49	2.09	11.2	16.1	16.2	19.8	31.0	Not possible
0.15	0.67		1.40	7.52	10.8	10.9	13.2	20.8	
0.075	0.48	0.71		5.36	7.72	7.74	9.37	14.9	
Jig 0.04	0.089	0.13	0.19		1.44	1.44	1.75	2.77	
No Jig 0.04	0.062	0.092	0.13	0.69		1.00	1.21	1.92	
0.02	0.062	0.092	0.13	0.69	1.00		1.21	1.92	
0.01	0.051	0.076	0.11	0.57	0.82	0.83		1.59	
0.005	0.032	0.048	0.067	0.36	0.52	0.52	0.63		
0.0025	Not normally possible								
% scrap expected			1	2	3	4	6	9	

NOTE: Machine tool normally used: turret/chuck/centre lathe and external grinder. Basis: 200 pieces in batches of 10.

Figure 10

COST OF ACCURACY OF ELEMENTS: PLAIN FACE RELATED TO A DATUM ON A FRAME OR BASEPLATE

Cost Ratios

Existing tolerance band FIM mm	Proposed tolerance FIM, mm							
	0.30	0.15	0.075	0.04	0.02	0.01	0.005	0.003
0.30		2.00	2.49	5.63	7.56	17.0	25.2	Not normally possible
0.15	0.50		1.25	2.82	3.78	8.48	12.6	
0.075	0.40	0.80		2.26	3.03	6.81	10.1	
0.04	0.18	0.36	0.43		1.34	3.01	4.47	
0.02	0.13	0.26	0.33	0.74		2.24	3.33	
0.01	0.06	0.12	0.15	0.33	0.45		1.48	
0.005	0.04	0.08	0.10	0.22	0.30	0.67		
0.0025	Not normally possible							
% scrap expected			1	3	6	10	15	

NOTE: Machine tool normally used: Vertical mill and surface grinder. Seals: Basis: 200 pieces in batches of 10.

Figure 11

RELATIVE MACHINING COSTS FOR TURNING METALS

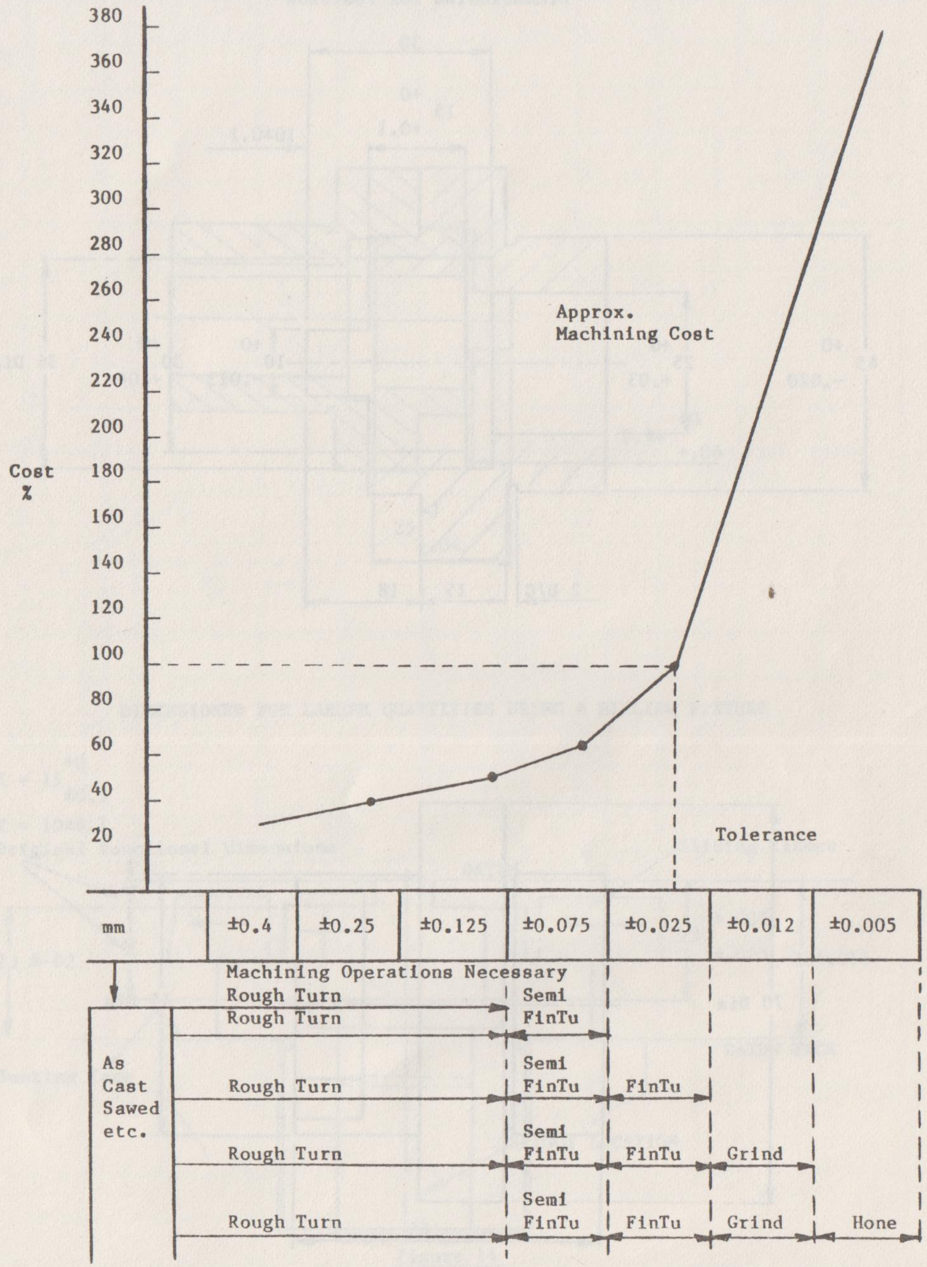
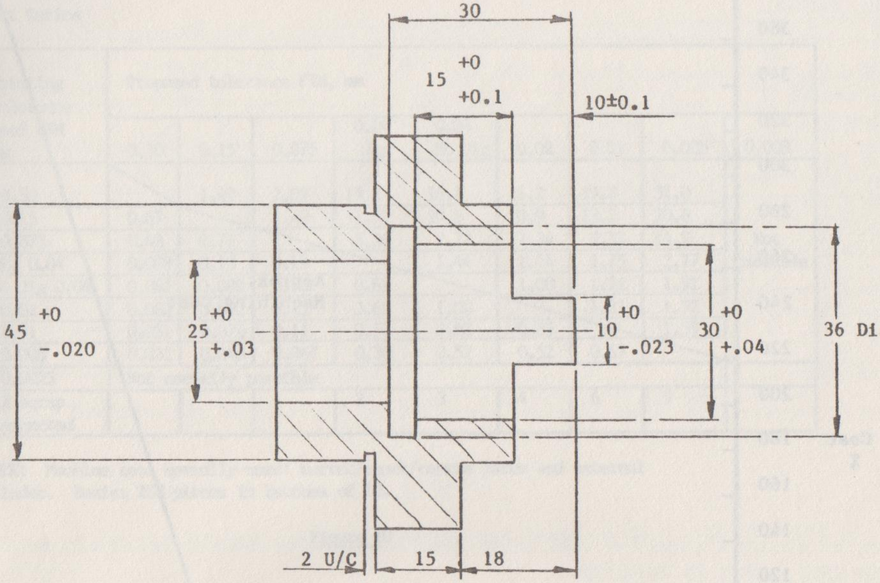
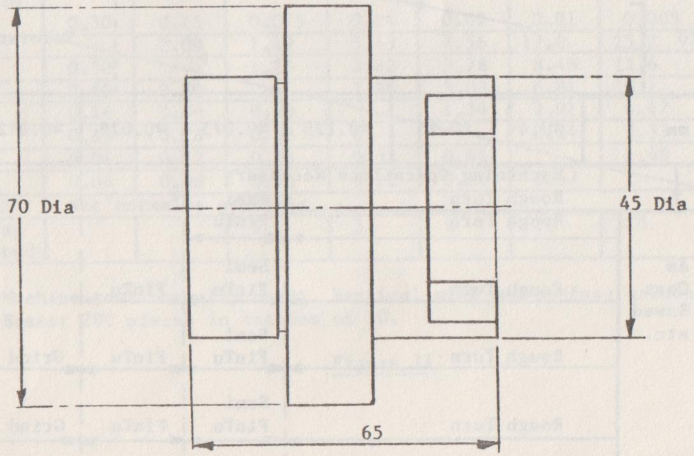


Figure 12

DIMENSIONING FOR FUNCTION





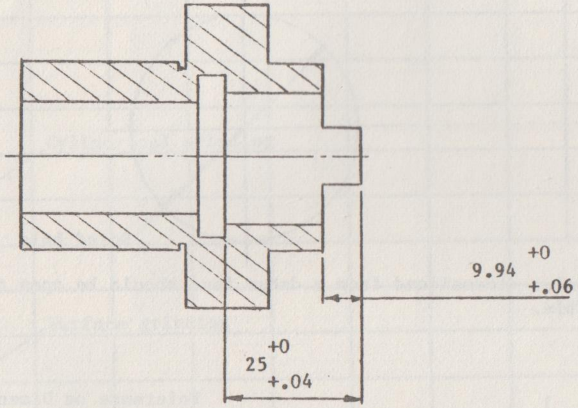
GENERAL TOLERANCE:
±0.25 UNLESS STATED.

√ALL OVER

SLEEVE

Figure 13

DIMENSIONED FOR SMALL QUANTITY PRODUCTION



DIMENSIONED FOR LARGER QUANTITIES USING A MILLING FIXTURE

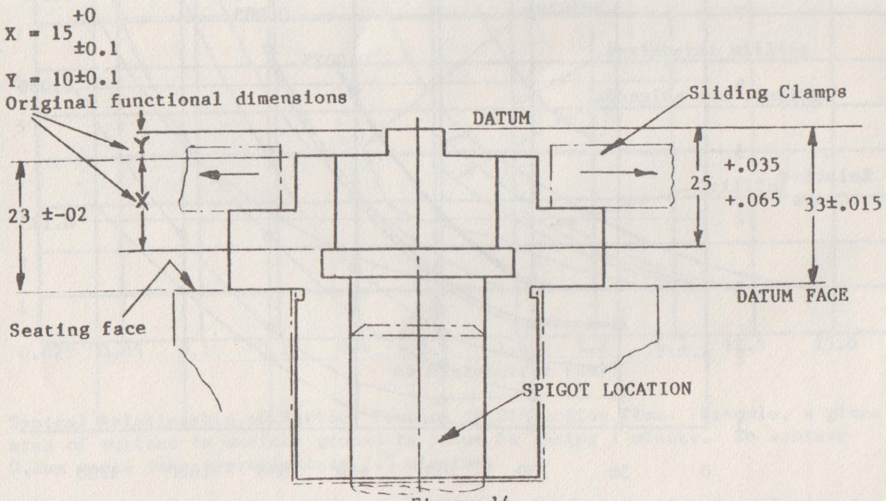
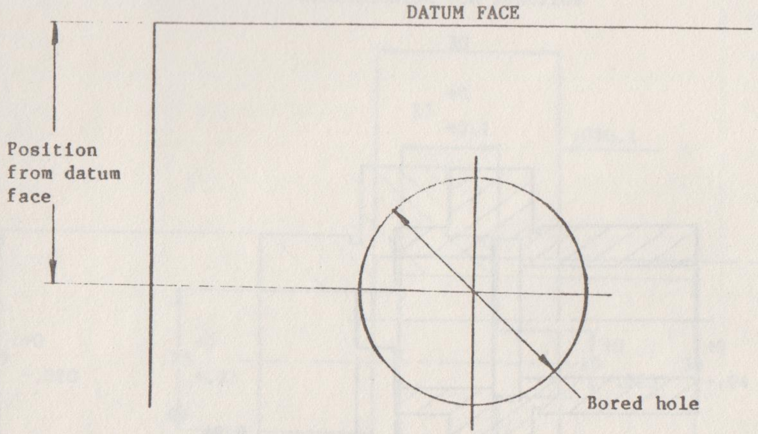


Figure 14

COST OF POSITIONING BORES IN RELATION TO A DATUM FACE



NOTE: All holes dimensioned from a datum face should be open tolerance wherever possible.

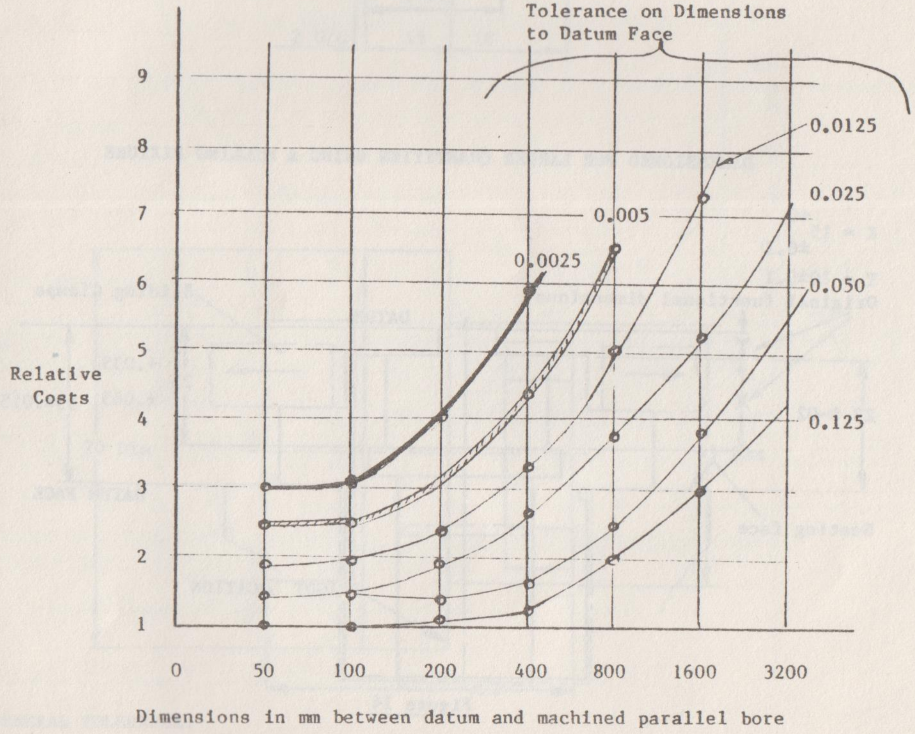
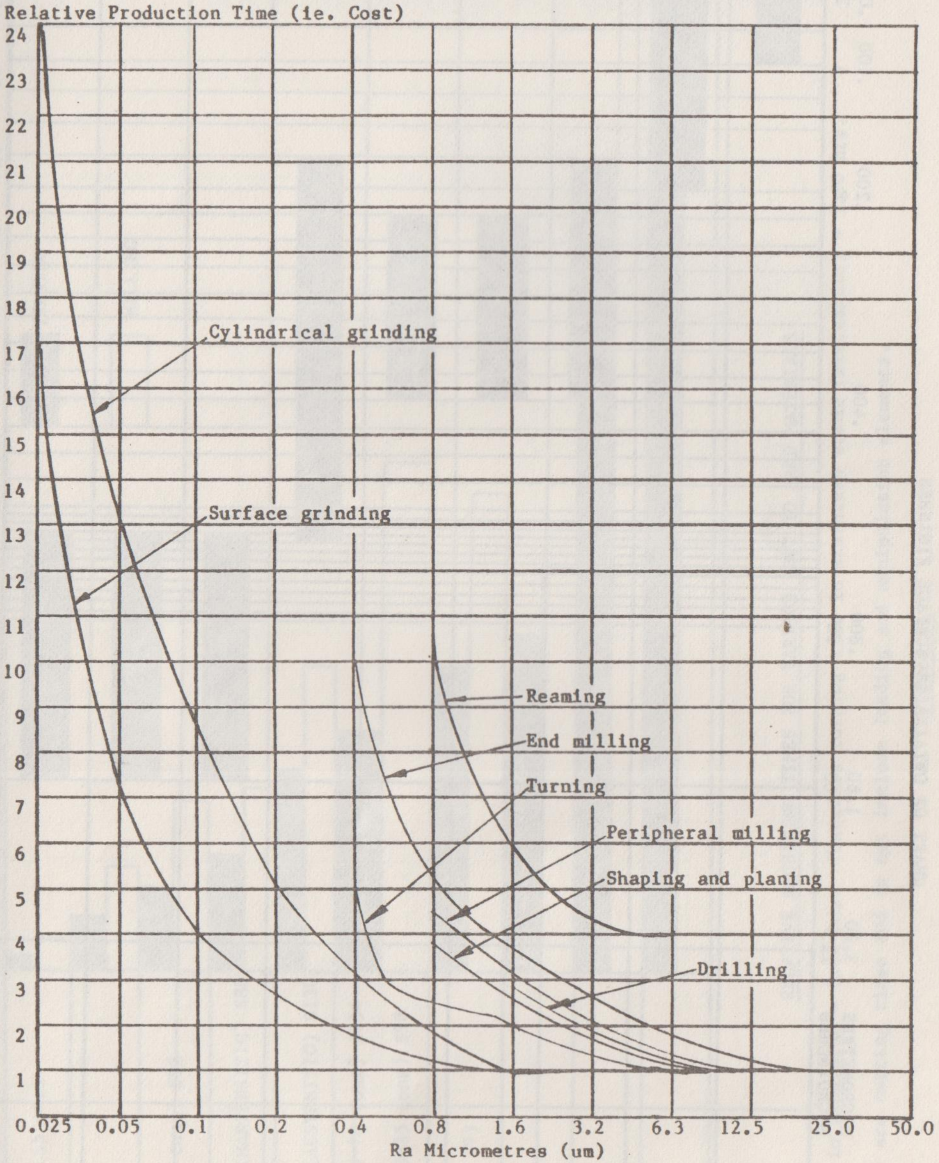


Figure 15

RELATIVE COSTS OF SURFACE TEXTURE



Typical Relationship of Surface Texture to Production Time. Example, a given area of surface is surface ground to 3.2um Ra taking 1 minute. To achieve 0.2um would take approximately 2.5 minutes.

The chart shows a series of curves displaying production time in relation to Ra values for the range of common machining processes, and is based on research carried out on machine tools from 1 to 10 years old. It is not intended to be used for making comparisons between different processes.

FIGURE 16

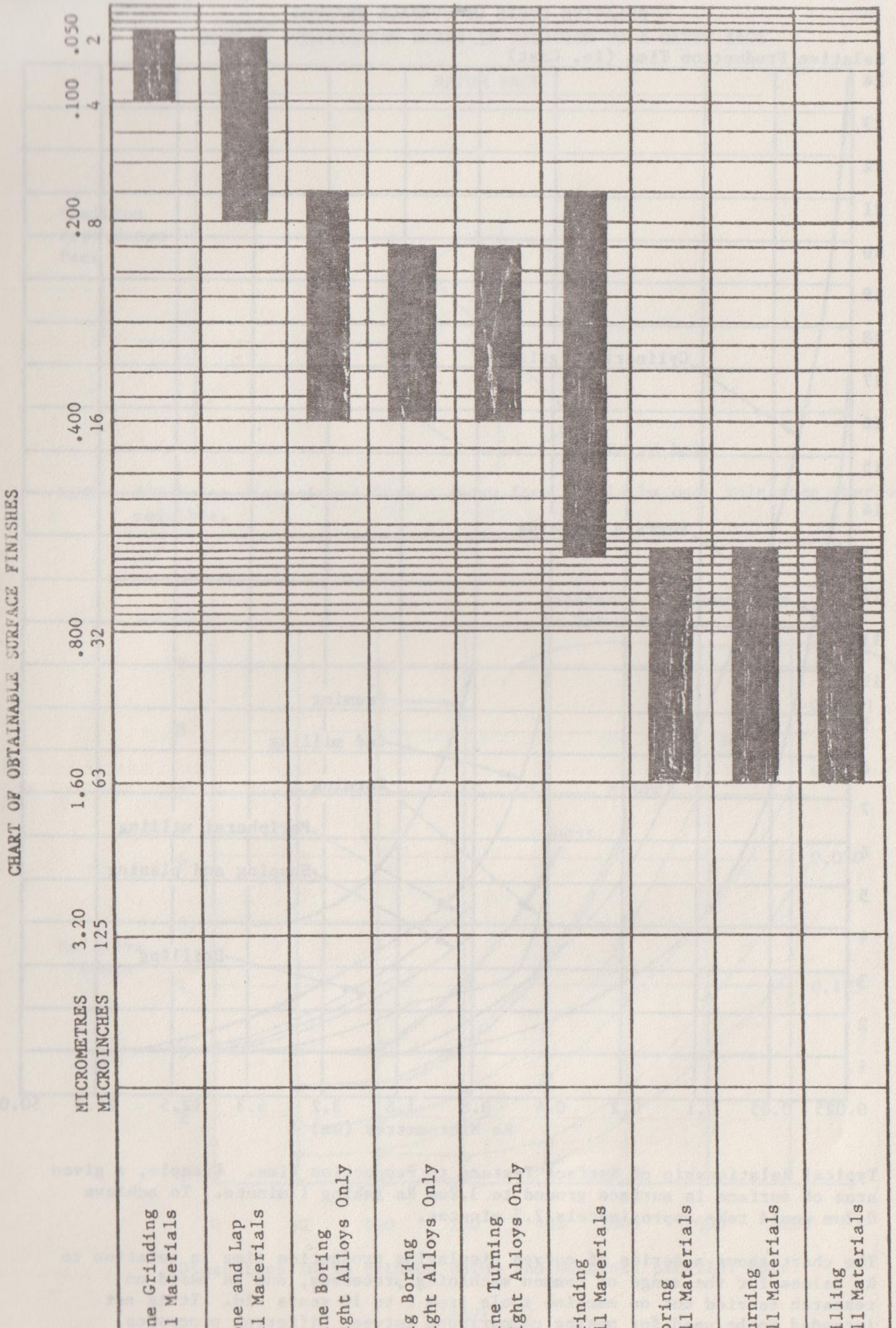
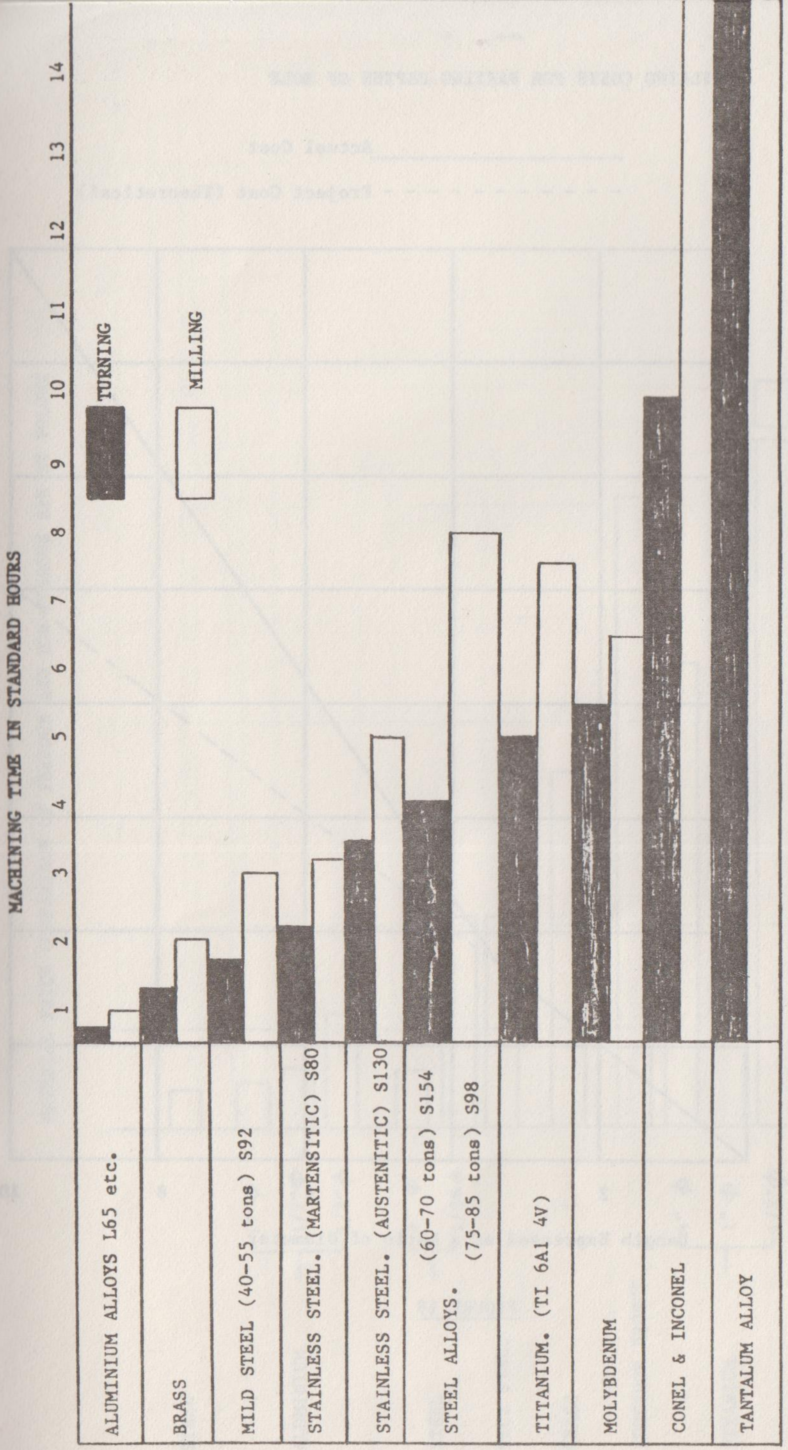


Figure 17



RELATIVE MACHINING TIMES FOR VARIOUS SOFT TO HARD MATERIALS

Figure 18

E.g. Turning time in aluminium = 0.50 hrs. Therefore turning time in stainless steel (austenitic) = 3.50 hrs.

NOTE: These times are cutting times and do not include loading and manipulation elements.

DRILLING COSTS FOR VARYING DEPTHS OF HOLE

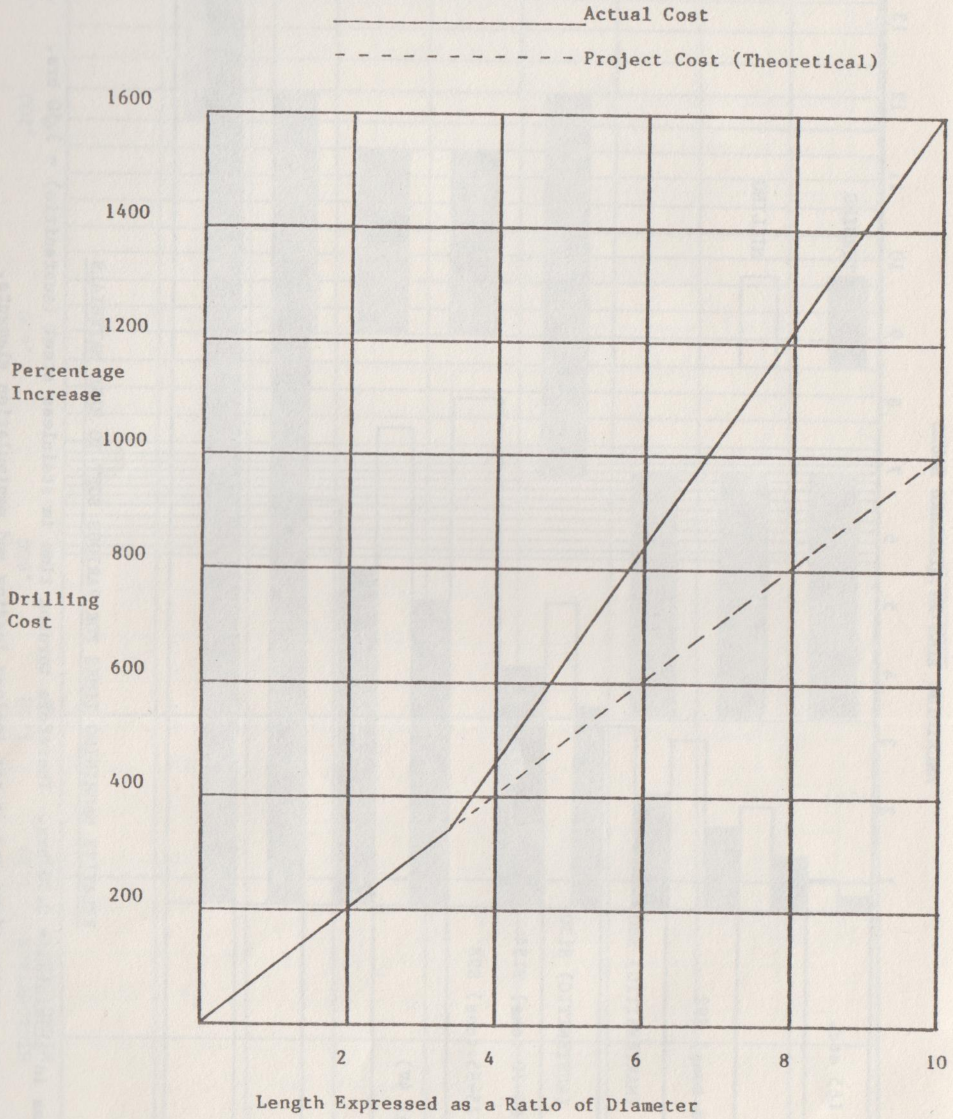


FIGURE 19

MATERIAL PRICE COMPARISON OF FERROUS AND NON-FERROUS BAR BY VOLUME

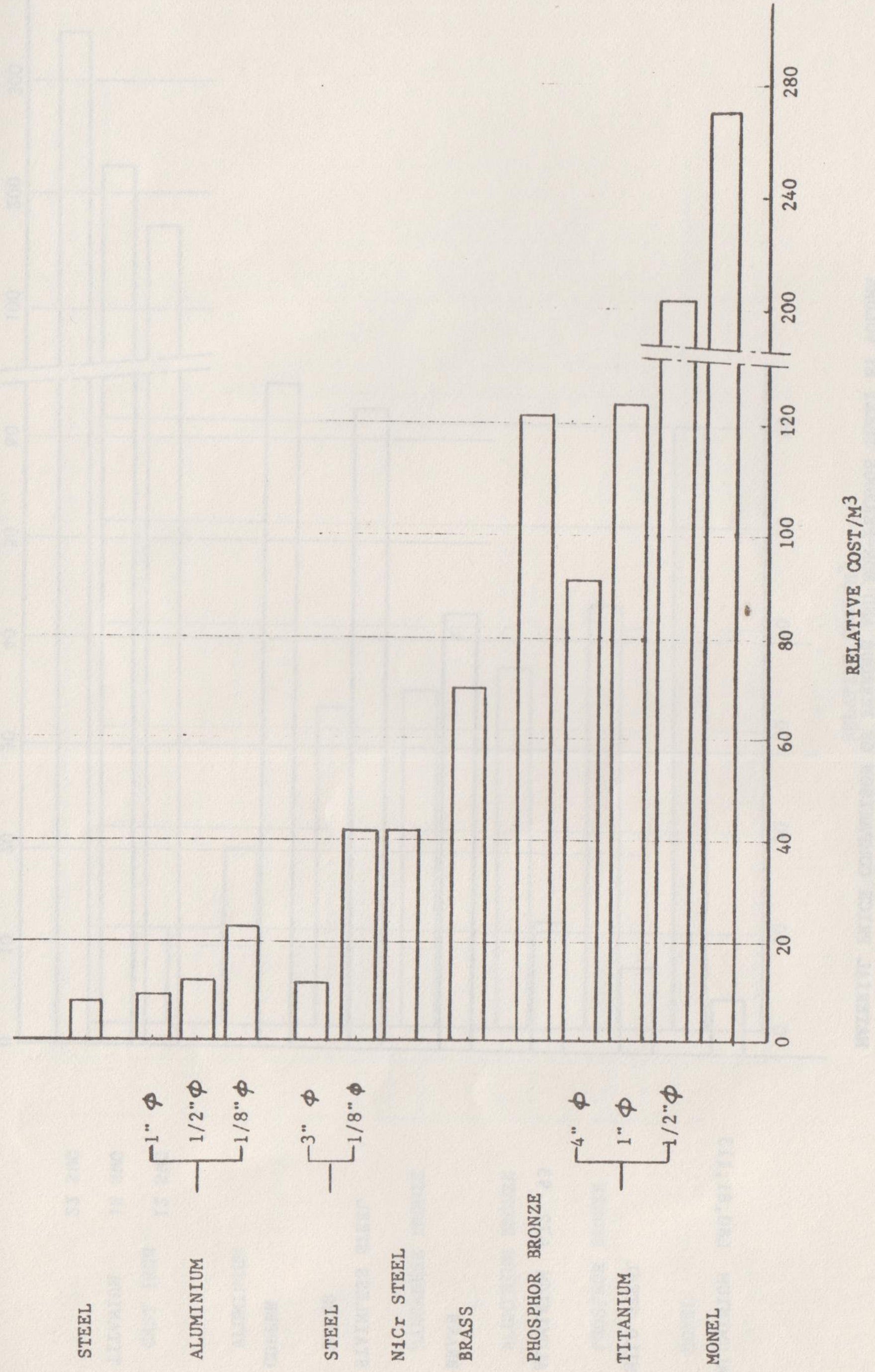


Figure 20

MATERIAL PRICE COMPARISON OF FERROUS AND NON-FERROUS SHEET BY VOLUME

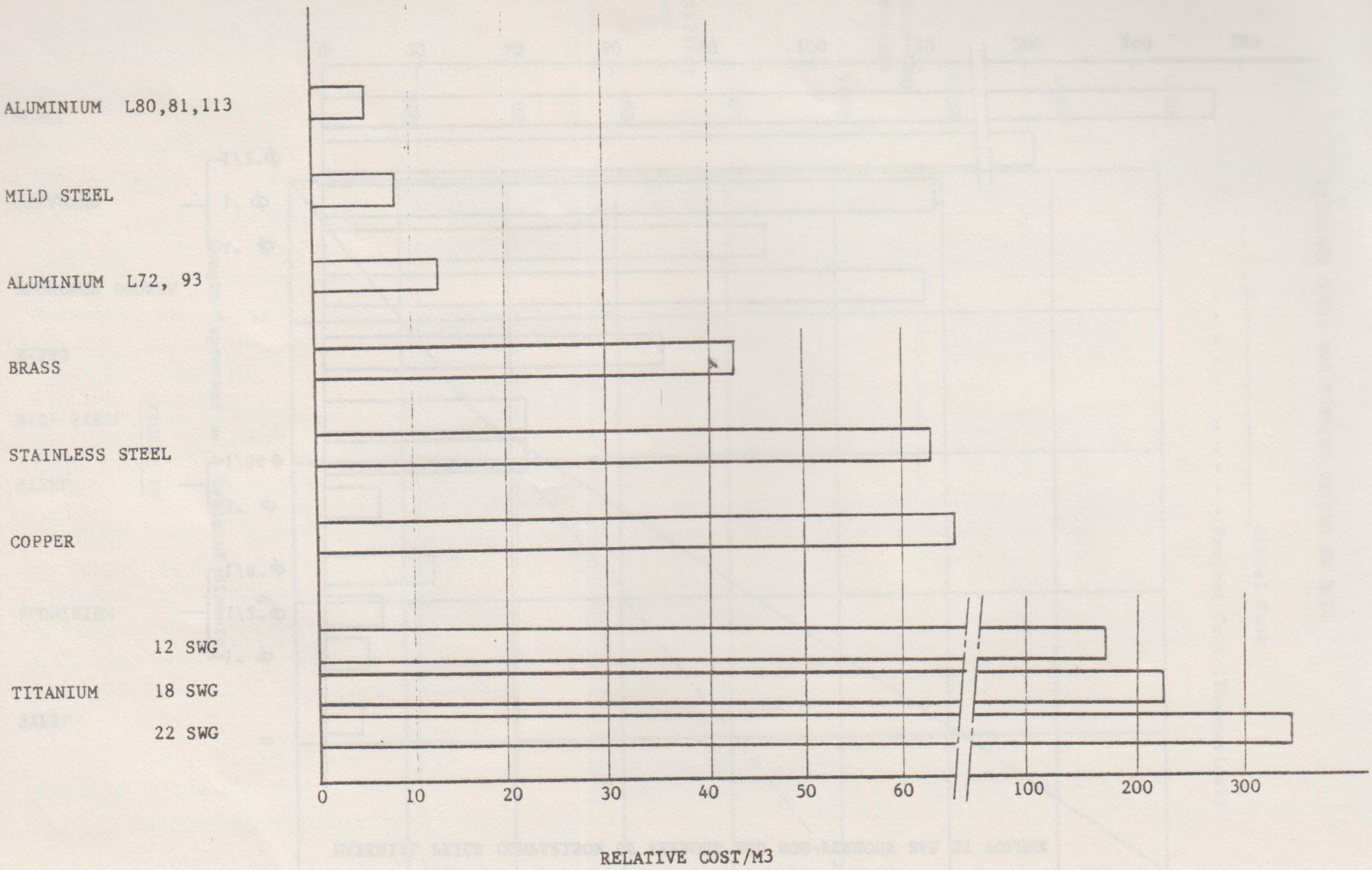


Figure 21

MATERIAL PRICE COMPARISON OF FERROUS AND NON-FERROUS CASTINGS BY VOLUME

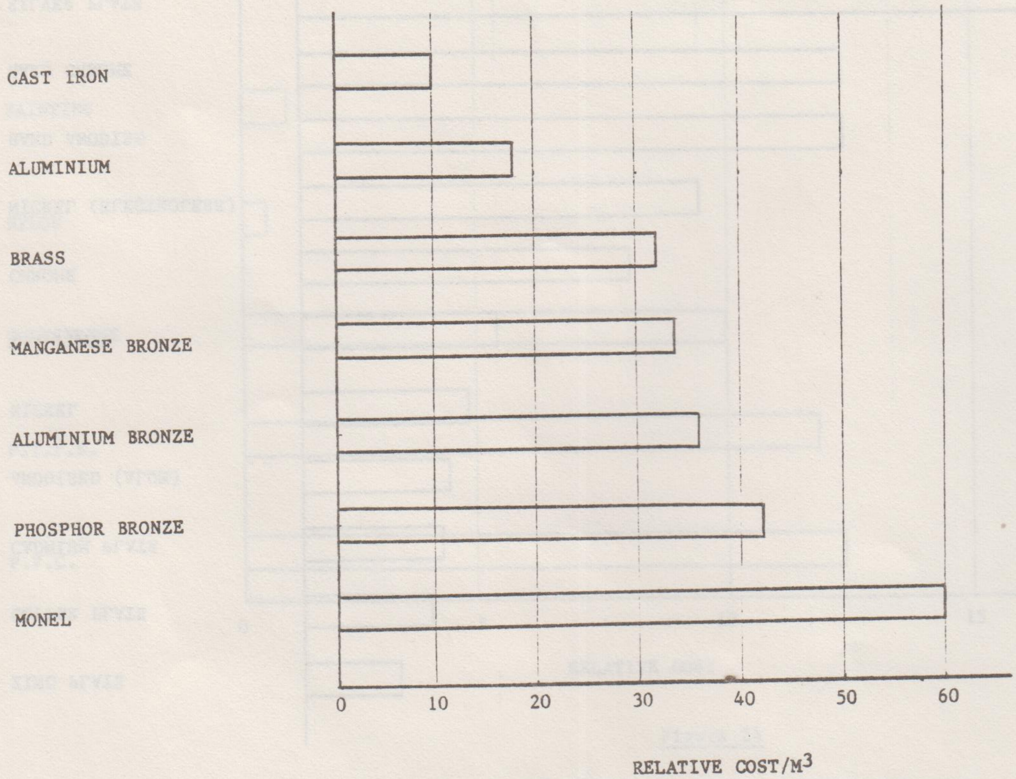


Figure 22

COST COMPARISON OF VARIOUS PLATING PROCESSES

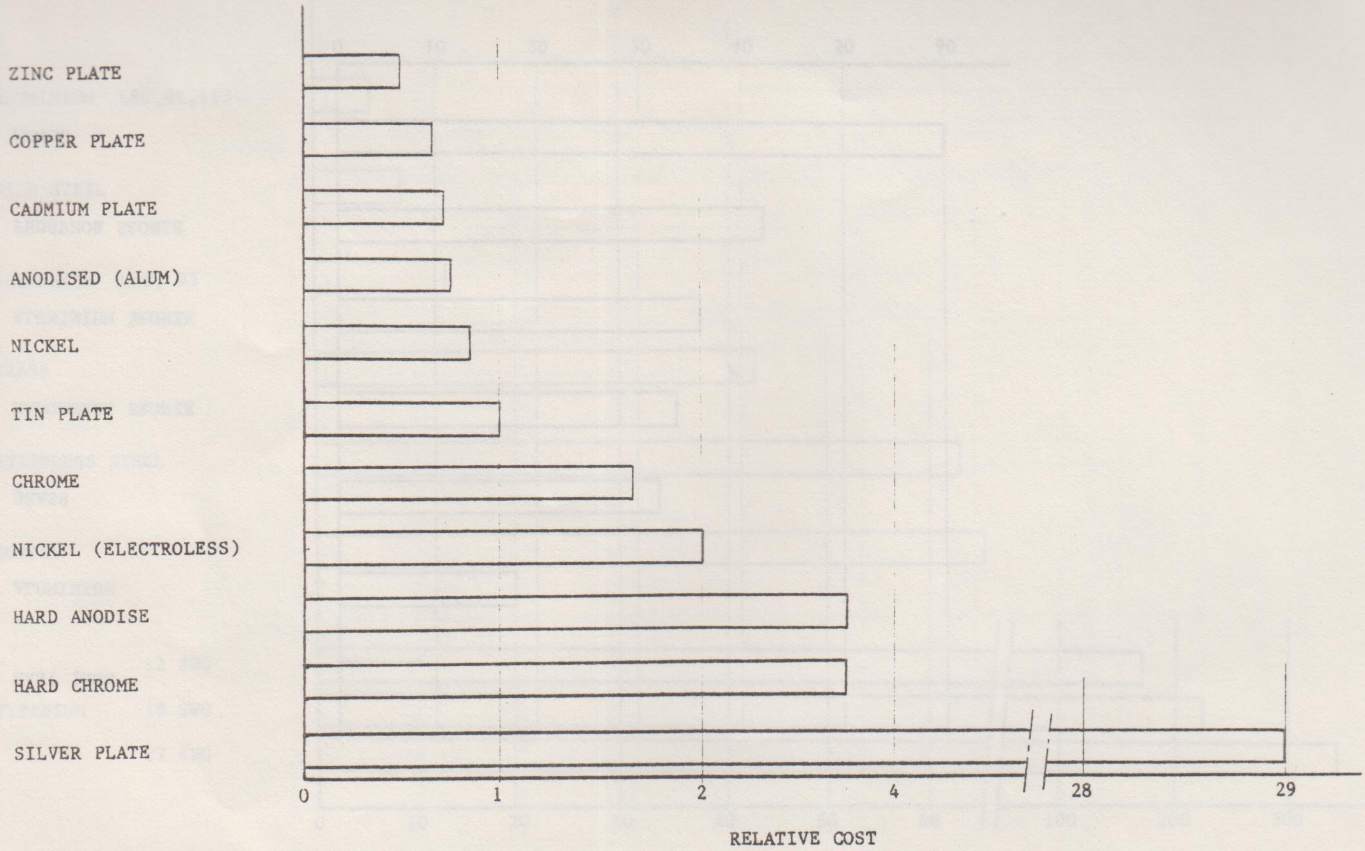


Figure 23

COST COMPARISON OF ALTERNATIVE FINISHES

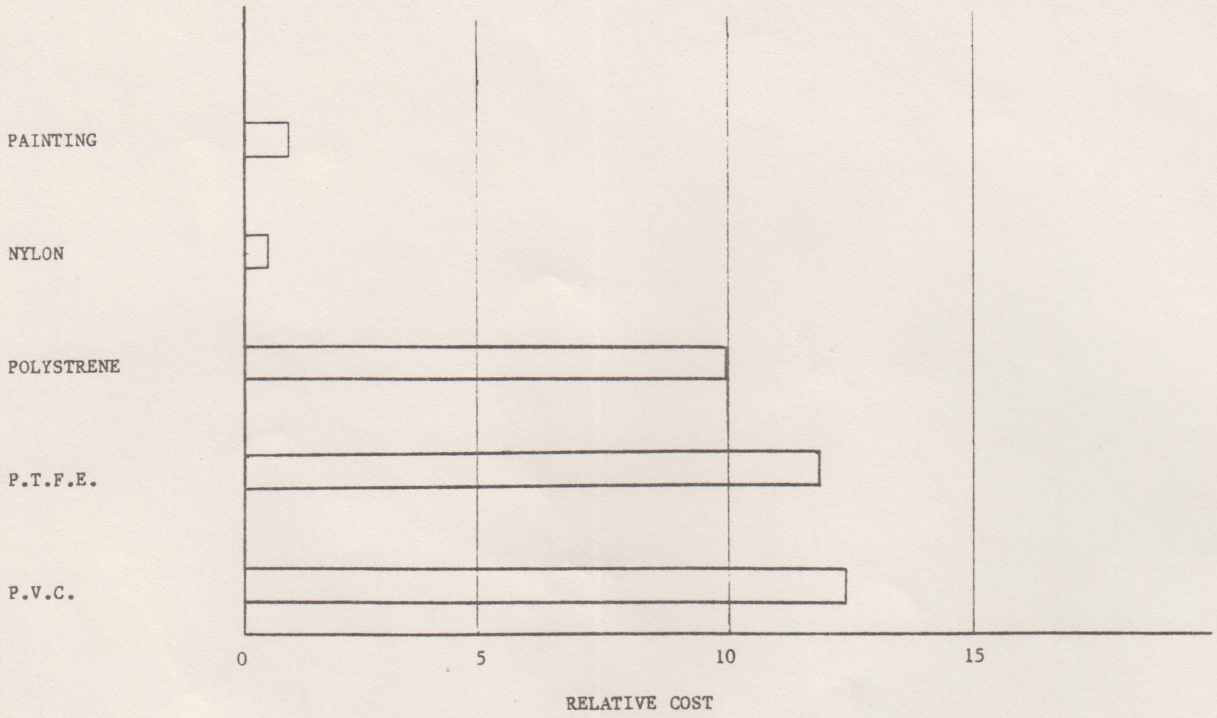


Figure 24